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DEVELOPMENT OF EXPERT SYSTEM FOR DESIGN OPTIMIZATION OF THE SCROLL COMPRESSOR

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ABSTRACT

This paper introduced the expert system for design optimization of the scroll compressor. The knowledges of this system are composed of theoretical models, experimental models and experiential knowledges. These knowledges mainly describe the relationships between dimensions and EER of the scroll compressor. Based on these knowledges and the design demands, by means of using the finite element method (FEM), the system can calculate the optimized dimensions of the scroll automatically. This system has designed the example scroll compressor, the performance of this scroll compressor is satisfying.

NOMENCLATURE

Cc_i -The i_{th} Constant Coefficient
d_i -The i_{th} Dimension
H_t -Refrigerant Enthalpy
L_c -Compression Loss
L_j -Journal Bearing Loss
L_t -Thrust Bearing Loss
L_f -Flank Friction Loss
L_{oo} -Friction Loss between Orbiting Scroll and Oldham Ring.
L_{fo} -Friction Loss between Frame and Oldham Ring.
n -Polytropic Coefficient
Pd -Discharge Pressure
Ps -Suction Pressure
r_o -Mass Rotio of Oil to Refrigerant in System
R_o -Orbiting Radius of Scroll
R_v -Built-in Volume Ratio of Compressor
V_c -Volumetric Displacement of Compressor
$\bar{V}_c$ -Volumetric Displacement Rate of Compressor
ΔH_e -Refrigerant Enthalpy Change in Evaporator
ΔH_o -Oil Enthalpy Change in Evaporator
ΔH -Vapor Enthalpy Increase in Shell
η_m -Motor Efficiency
η_v -Volumetric Efficiency
ρ_t -Density of Refrigerant Vapor

INTRODUCTION

The popularization of air conditions requires improvement in the energy efficiency ratio(EER). Thus, to determine the dimensional optimization and to predict the performance potential for various displacement scroll compressor are very important[1].

The dimensional optimization is based on many complex models, which include theoretical models, experimental models and experiential models[2, 3]. When the structure of the compressor changes, the parameters of the models vary as well. In addition, the selections of parameters do not all depend on the numetric calculation. In many case, it is decided by the experiential knowledges. In order to resolve these problems very well, one field of artificial intelligence(AI)—— Expert System is very helpful[4].

This Expert System for optimization design of the scroll compressor is designed specially, it has four functions: (1) System Models Management; (2) Calculation of Scroll Parameters; (3) Selection of Dimension of the Scroll Compressor (4) Simulation of Deformance by means of the Finite Element Methods (FEM). The results are put into the data base(DB) that CAD/CAM enjoys.

OPTIMIZING MODELS AND CONSTRAINT CONDITIONS

Optimizing Model

An orbiting scroll is shown in Fig. 1, it is mainly made up of wrap and end plate. A wrap can be described by involute generating radius(Rg), involute starting angle (α), Number of scroll compressing chamber(N), vane height(H), they are called as the base parameters of scroll (PAR). The other geometrical entities can be described by dimensions(DIM).

With many years study of the scroll compressor, we found that its performance depends on the PAR and DIM directly. All dimensions (DIM) of the scroll compressor can be deduced from the PAR. So the powerful analytical models which resulted in optimization of the basic PAR and DIM of the scroll compressor is very important.

The efficiency of the hermatic refrigerating compressor is usually described by energy efficiency ratio (EER):

$$\text{EER} = \frac{\text{Evaporator heat, } Qe}{\text{Input Power, } W_{in}} \tag{1}$$

If the operating condition is known, the capacity and the input power of compressor can be expressed as [1]:

$$Qe = (\Delta H_{e} - \Delta H_{o} r_{o})\ (\overline{V_{c}}\ \eta_{v}\ \rho_{t} H_{t} / (H_{t} + \Delta H)) \tag{2}$$

and

$$\Delta H = W_{in}(1 - \eta_{m}) + L_{c} + L_{j} + L_{t} + L_{f} + L_{oo} + L_{fo} \tag{3}$$

$$W_{in} = \left(\frac{n}{n-1} \left(\frac{Pd}{R_{v}} - Ps \right) \overline{V_{c}} + L_{c} + L_{j} + L_{t} + L_{f} + L_{oo} + L_{fo} \right) \frac{1}{\eta_{m}} \tag{4}$$

With further expansion limited to the scaling relations, all components of equation (2), (3) and (4) may be written using only constant coefficient [Cc] and the four independent variables Rg, α, N and H. Usually, numerical values for the constant coefficient were obtained through a combination of calculation and empirical analysis of the experimental compressor. However, determining constant coefficient [Cc] is not easy, sometimes very difficult. So the problem focuses here.

By study of this paper, we found that Cc is not always 'constant', it is related to the structure and dimension of the scroll compressor. We have built this kind of models, which described the relationships between dimensions and Cc, it may be simply expressed as:

$$Cc_{i} = F1_{i}(d_{1}, \cdot \cdot \cdot, d_{i}) \tag{5}$$

In the other way, according to the field expert experience and physical models, we have built other kinds of models, the dimensions of the scroll compressor can be achieved through them, written as:

$$d_{i} = F2_{i}(\alpha, N, H, Fg) \tag{6}$$

Upon the substitution of equation (2) ~ (4) in equation (1), Equation (1) may be expressed simply as follow:

$$EER = F(\alpha, N, H, Fg, Cc_{i}) \tag{7}$$

The process of optimization is separated into two steps. The first step is called as parameters optimization, its object is to find the optimal value of Rg, α, N and H so as to make the value of EER maximum. The second step is dimension optimization, through which finds the best dimensions of scroll compressor to which make the deformation of the scroll minimum.

Constraint Conditions

According to the design limitation, and the demands of strength, stiffness, machining precision, some constraint conditions are made as follow:

(I) $Vc=4\pi Rg^2(\pi-2\alpha)(2N-1)H$ (8)

This condition makes the compressor having a positive displacement.

(II) $Tmin < 2Rg\alpha < Tmax$ (9)

This equation is made by strength, stiffness of the wrap so as to make sure of the mininum deformation when scroll is being machined or working.

(III) $H < Hmax$ (10)

When V_c is known, the big height may reduce the amount of leakage, but it reduces the stiffness of scroll wall and makes machining precision low, thus the height should have a limitation.

(IV) $4N\pi Rg < Dmax$ (11)

This prevents the Diameter of compressor from too big.

To sum up, the optimal model may be written as:

$$(EER)_{max}=maxF(Rg,\ \alpha, N, H, Cc_i)$$
$$d_i=F2_i(\alpha, N, H, Rg)$$
$$Cc_i=F1_i(d_1, \cdot\cdot\cdot, d_i)$$

$$\text{subject to :} \left[\begin{array}{l} Vc=4\pi Rg^2(\pi-2\alpha)(2N-1)H \\ Tmin < 2Rg\alpha < Tmax \\ H < Hmax \\ 4N\pi Rg < Dmax \end{array}\right. \quad (12)$$

Structure of Expert System and Flow of Optimization

The structure of ES for design optimization of the scroll compressor is shown in Fig. 2. It is composed of Knowledge Base (KB), Knowledge Base Management (KBM), Data Base (DB), Inferencer, Optimizer and Interface. All models of scroll compressor are stored in the KB. At the beginning, with the help of INFERENCER, ES gets models from KB and data from DB and starts to run, the result is put into the DB. KBM serves the KB for updating or revising the models.

The flow of optimization calculation is shown in Fig. 3. After inputing the design specification, the system get all initial value of constant coefficient in the EER model (expressed by a set $[Cc_0]$) and starts to run. The results of PAR(Rg, α, N, H) is put into the DB. According to equation (6), the 3D dimensional model of a part can be built up, then a simulation of deformation can proceed by means of using Finite Element Methods (FEM) [5]. If the deformation is not satisfying, according to equation (5), [Cc] should be modified, runs the system again.

RESULTS

In order to verify the optimal model, several design specification are made to calculate the numerical value. Here is a result about the condition of $Vc=75cm^3$, $Rv=2.7$ (shown in Fig. 4, Fig. 5 and Fig. 6) . The result of optimized parameters are: Ro=4.44mm, Rg=2.56mm, t=3.602mm, H=37.98mm. Using these results, an example scroll compressor was designed and manufacured, its performance is satisfying.

CONCLUSION

This ES for design of scroll compressor is powerful. Author treat "Cc" as a fuction of dimension of the scroll compressor, put the parameter (PAR) optimization and the dimension (DIM) optimization together, by means of self -teaching methods, the analytical models of optimization have been built up. As a result of experimental study, they are very near to realistic conditions.

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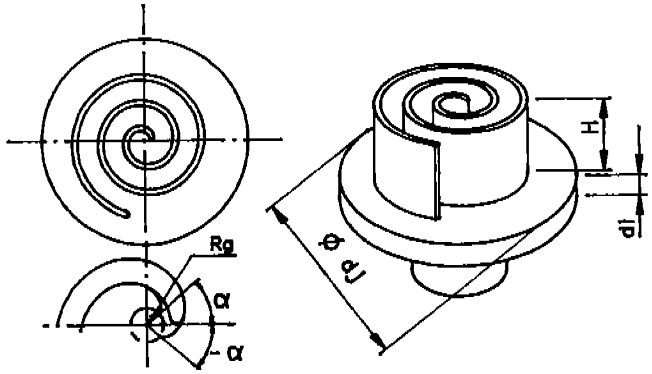

Fig.1 Parameters and Dimensions of an Orbiting Scroll

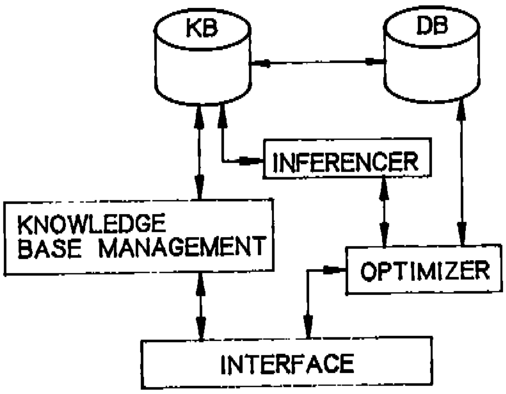

Fig.2 Structure of ES for optimization

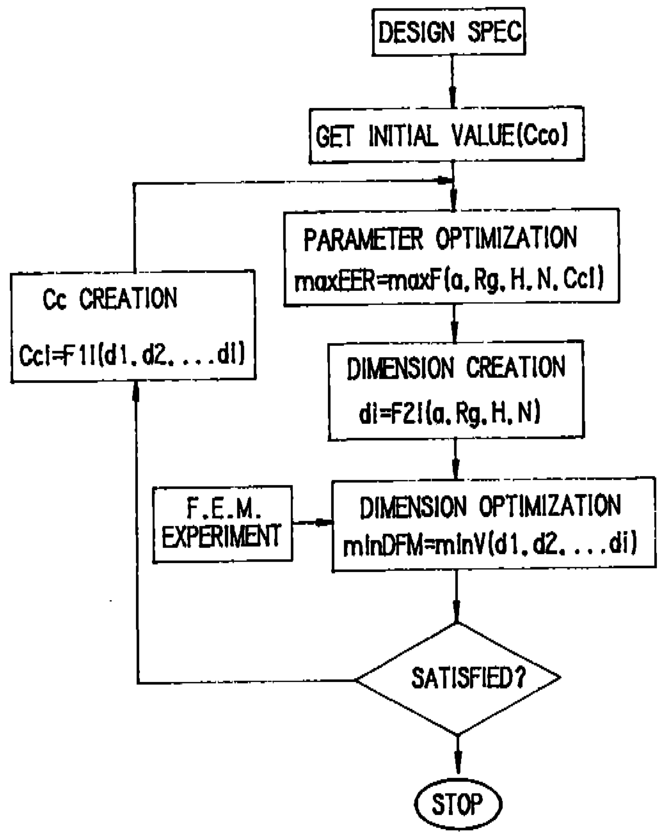

Fig.3 Optimization Algorithm

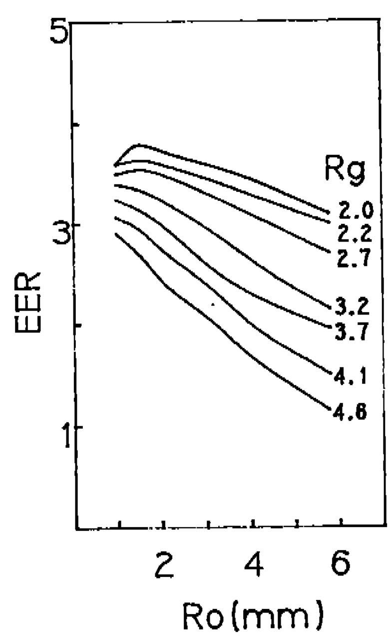

Fig.4

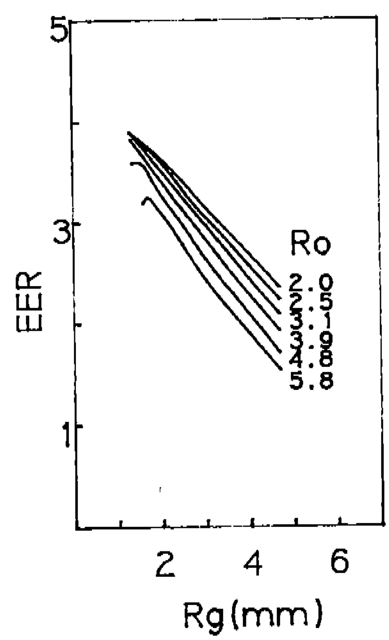

Fig.5

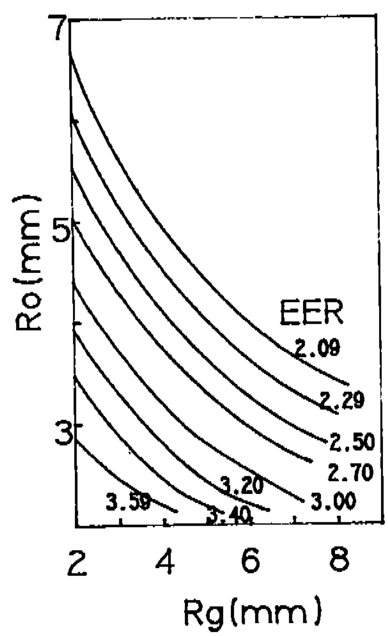

Fig.6